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U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

Technical News

BULLETIN

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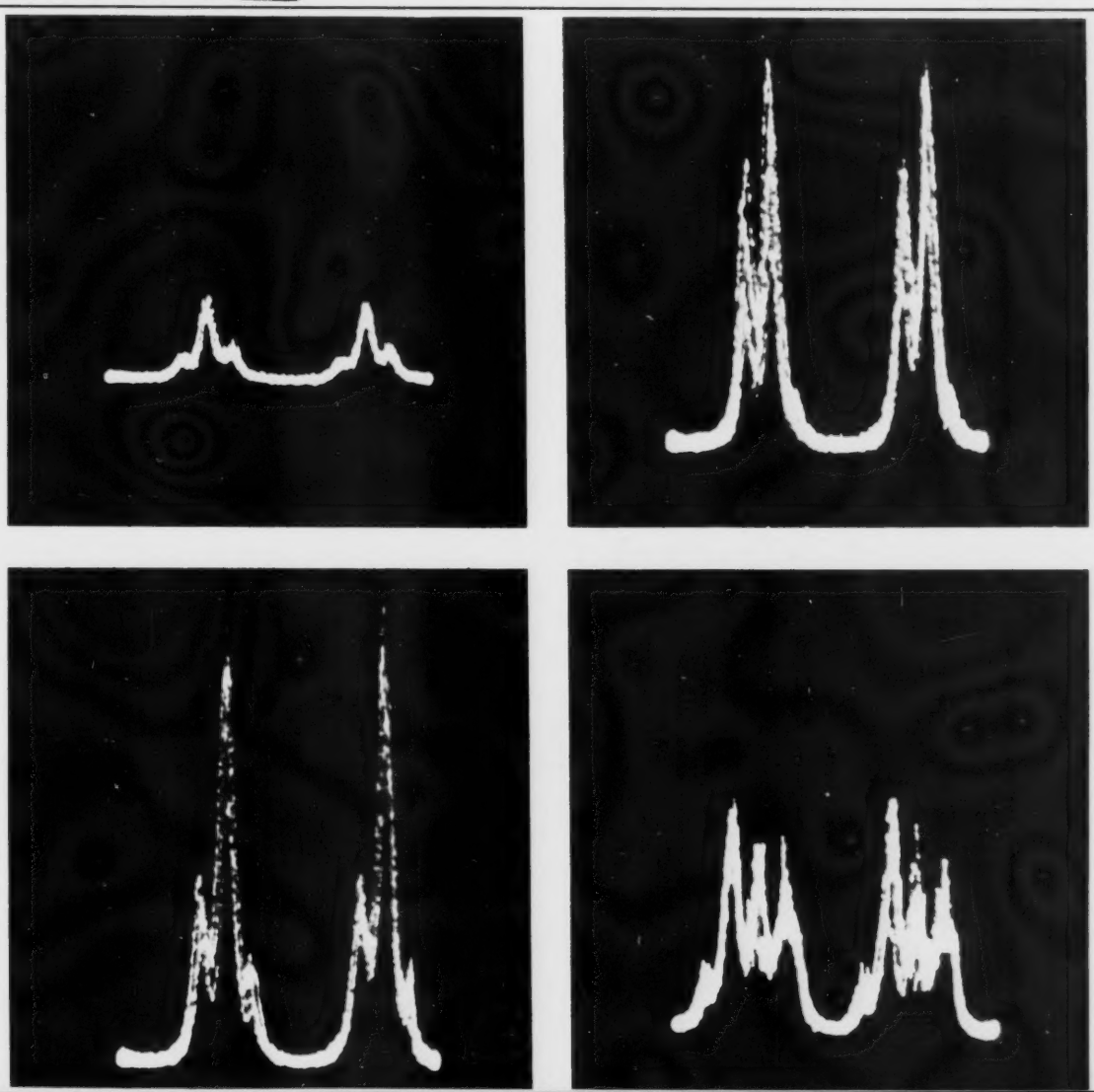
VOLUME 48 MARCH 1964 NUMBER 3



U.S. DEPARTMENT OF COMMERCE — LUTHER H. HODGES, *Secretary*

NATIONAL BUREAU OF STANDARDS — A. V. ASTIN, *Director*

NATIONAL BUREAU OF STANDARDS

Technical News

BULLETIN

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Subscription price: Domestic, $1.50 a year; 75 cents additional for foreign mailing; single copy, 15 cents. Use of funds for printing this publication approved by the Director of the Bureau of the Budget (June 19, 1961).

Library of Congress Catalog Card Number: 25–26527

March 1964 — Issued Monthly — Vol. 48, No. 3

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COVER: Laser modes resolved with a newly designed spectrometer at the Bureau. The instrument resolves interference fringes on either a strip chart or, as in this case, an oscilloscope screen. Analyses of the laser spectrum obtained with the new instrument are expected to aid in achieving laser frequency stabilization. The oscillograms on the cover were chosen at random to demonstrate the continuously changing patterns that are obtained. (See page 46.)

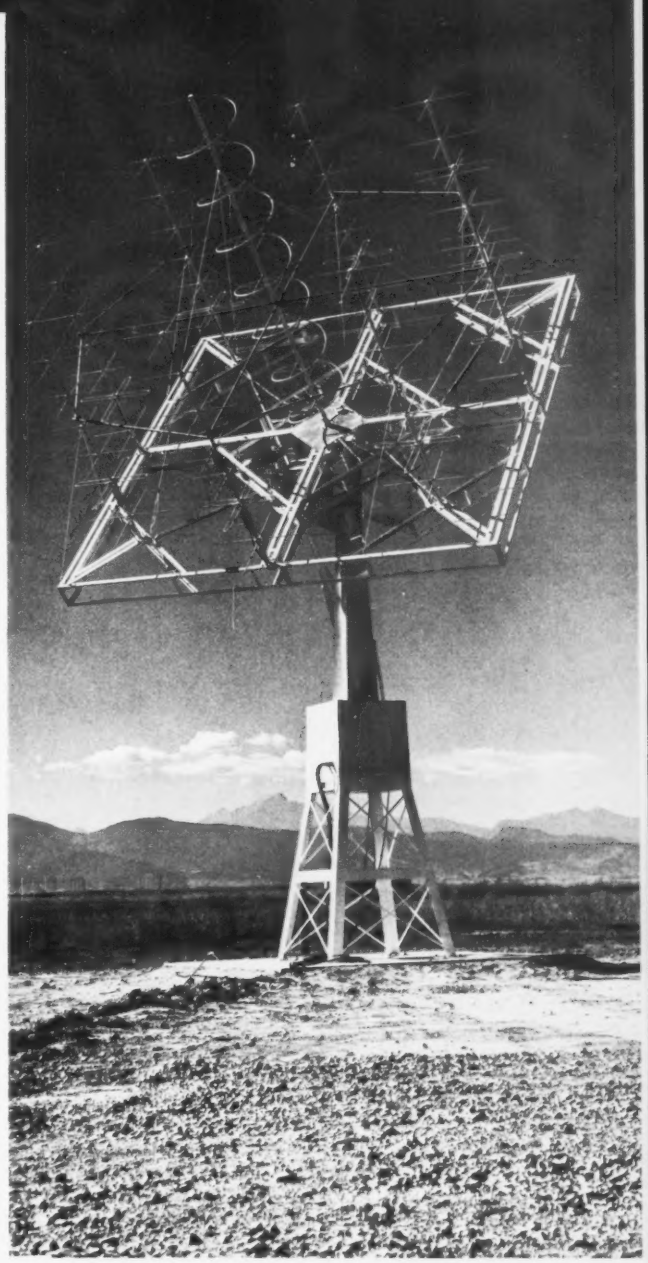
New NBS Installations Aid U.S. Space Programs

The NBS Central Radio Propagation Laboratory is adding three new installations to its globe-girdling network of radio research stations. A satellite telemetry station, recently completed at Boulder, Colo., will receive and control information from TOPSI, a topside sounder satellite to be launched by the National Aeronautics and Space Administration as part of an international program to probe the ionosphere from above. Two ionospheric vertical sounding stations, one in California and the other in Virginia, will make ground-based soundings of the ionosphere. Data obtained by these two stations will be used to determine the suitability of rocket and satellite launching times for the Pacific Missile Range and NASA's Wallops Island (Va.) Range, respectively. The observations also augment NBS programs in ionospheric physics and radio propagation.

Satellite Telemetry Station

At frequencies below about 30 Mc/s, long-distance radio communication, especially to craft in space, is greatly influenced by the ionosphere's changing layers of ionization. These layers are studied by means of ionospheric radio soundings using a sweep-frequency device similar to radar at many ground stations around the world. However, it is in the nature of this technique that it provides no data above the peak of the reflecting layer. Studying the ionosphere from above with this technique was shown to be feasible by a series of topside sounder rocket flights in 1961 and has been employed systematically since the launching of the Alouette topside sounder satellite in September 1962.

Space scientists will communicate with the second topside sounder satellite TOPSI (designated S–48 by NASA) by means of a chain of telemetry stations, coordinated by one such station just completed at the Bureau's Gunbarrel Hill field station, near Boulder, Colo. The NBS station consists of an antenna array and electronic equipment in an adjoining small house. Eight Yagi antennas form a highly efficient and directional array to receive the signals telemetered from the satellite. The ninth antenna, a helix mounted in the center of the Yagi array, is used to transmit commands



This new antenna array at the NBS Gunbarrel Hill (Colo.) field station will be used to communicate with TOPSI, a topside sounder satellite to be launched by NASA in 1964. The array consists of eight Yagi antennas for receiving telemetered data and a single helix for transmitting instructions to the satellite. All are mounted on a frame which is turned and elevated in use so that it is always pointed at the satellite.

to the satellite. The entire antenna array is mounted on a movable platform which can be tilted and rotated to follow the satellite as it passes in orbit over the station. The Bureau's ionospheric research scientists expect the station to receive ionospheric data from the TOPSI satellite as it follows the 5,000-mi-long section of its orbital path above the Boulder horizon. The station has already been tested successfully on several occasions, receiving data from the Alouette satellite on command.

Ionospheric Sounding Stations

Rocket and satellite experiments in the upper atmosphere and near-space, and the launchings carried out in missile development, require extensive use of ground-based methods by which certain properties of the upper atmosphere may be measured continuously. One such important method is that of sweep-frequency ionospheric sounding, from which the ionization of the high atmosphere (100 to 300 km) may be monitored. Many rocket launchings must await suitable conditions for optimum experimental results, and these conditions may be detected and even predicted by an ionospheric sounding station.

One of the two new field stations is located at the Navy's Pacific Missile Range, Point Arguello, Calif., as a result of an agreement between the Bureau and the Navy. The other, at NASA's Wallops Island (Va.) launching site, followed a similar agreement with NASA. The Navy and NASA have assumed the installation and major equipment costs, while the Bureau provides the personnel and technical supervision.

The Bureau's Vertical Sounding Research Section operates the two stations and undertakes data analysis and consultation for many of the range-using agencies. Developments of improved instrumentation and some ionospheric studies are carried out at the stations.

Spectrometer for Laser Analysis

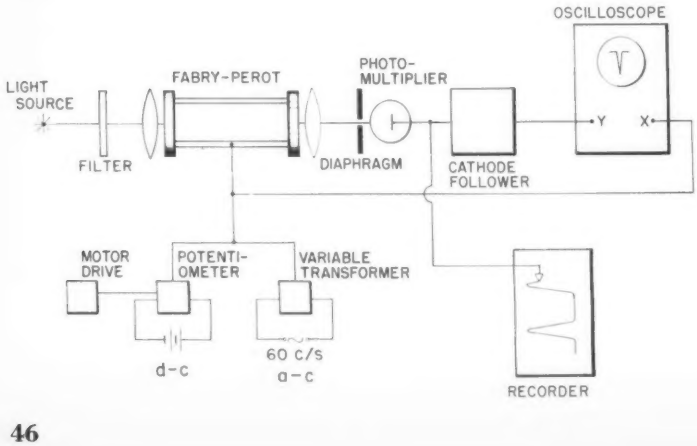
A VERSATILE, convenient-to-use spectrometer has been constructed at the Bureau to study laser frequencies. Designed by K. D. Mielenz, R. B. Stephens, and K. F. Nefflen, the instrument automatically varies the separation between two interferometer mirrors to scan the spectrum of a light source. The resulting interference patterns are reproduced on either a strip chart or an oscilloscope screen. In experiments thus far conducted, the instrument has been found to have quick response, high resolving power and intensity, and good reproducibility.[1]

In research to extend the range of accurate length measurements, the Bureau recently investigated the use of a helium-neon laser as a light source in interferometric measurements of length.[2] The laser successfully produced sharp interference patterns over a 200-m optical path, but its frequency of oscillation tended to be unstable. To adjust the laser to a precise frequency, additional data are needed on frequency output. The purpose of the present work is to obtain such data.

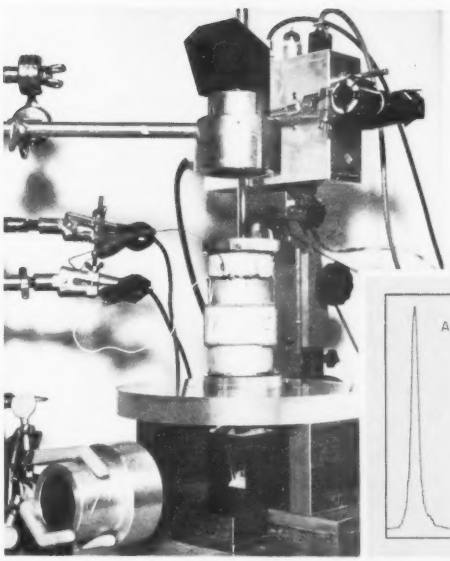
Instrument Design

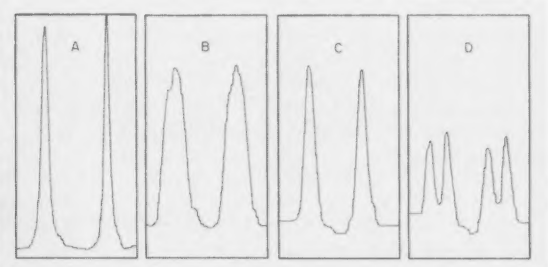
An intrinsic component of the spectrometer is a piezoelectric ceramic tube that is used as a spacer for a Fabry-Perot interferometer (two plane, parallel, partially transmitting mirrors). Voltages to provide linear changes in the tube are applied through wires soldered to the inside and outside of the tube. The ceramic in the tube is primarily a capacitive circuit element, so that only a small charging current is drawn when voltages are applied. The d-c voltage required for a continuous linear expansion or contraction of the tube is obtained with a simple filtered power supply or dry batteries. The a-c voltage required for tube oscillation is obtained from a 60-cycle power line.

In exploratory experiments, the light beam was transmitted through a collimating lens in front of the instrument and a telescope lens behind it. A small circular diaphragm placed in the optical path permitted only the center of the circular interference fringe pattern to be viewed by a photomultiplier tube.



Block diagram of a spectrometer constructed to study the properties of lasers. Interference patterns may be either recorded on a strip chart or displayed on an oscilloscope screen with this instrument. Both a-c and d-c voltages are required to obtain the oscilloscope display.





Left: **Spectrometer designed to detect laser frequencies and modes of oscillation. Principal component is a piezoelectric ceramic tube** (*center*) **which is used as the spacer for two plane, parallel, partially reflecting mirrors. The laser beam is transmitted through a collimating lens** (*lower left*), **a telescope lens** (*upper center*). **Two pentaprisms** (*top and bottom*) **are placed in the optical path to achieve a compact arrangement of the apparatus. Interference fringes obtained as a function of variable mirror separation are viewed by a photomultiplier tube through a small circular diaphragm (both at upper right).** *Right:* **Four different patterns obtained when a mercury light source was used in the NBS spectrometer. (a) Pattern observed when no magnetic field is applied to the light source. (b) Line broadening by the Zeeman effect occurs when a magnetic field is applied. (c) Insertion of a filter in the optical path isolates the two Zeeman parallel components. (d) A 90-deg rotation of the filter isolates the Zeeman perpendicular component.**

As the mirror separation of the interferometer was altered by the movements of the piezoelectric tube over a period of time, the light passing through the diaphragm yielded a record of the intensity structure within the fringes. The photomultiplier tube was connected to an automatic recorder or an oscilloscope, so that this structure could be traced on the strip chart or displayed on the oscilloscope screen.

A block diagram of the instrument is shown with recorder and oscilloscope in the schematic.

Experimental Results

Two similar setups were used in these experiments, one with a mirror separation of 8 mm and one with a separation of 10 cm. In the 8-mm arrangement, a mercury 198 lamp was used as the light source, and a combination of filters was employed to isolate the 5461 Å spectral line of the source. When d-c voltage was applied to the piezoelectric tube, a clear record of this line was obtained on the strip chart. When, in addition, a magnetic field was applied to the lamp, a line broadening by Zeeman effect was observed. Insertion of a filter in the optical path served to isolate the two parallel Zeeman components. When the filter was rotated through a 90-deg angle, only the perpendicular Zeeman component appeared (see illustration).

In the 10-cm arrangement, a helium-neon laser was employed as the light source. A cathode follower inserted between the phototube and the oscilloscope provided an impedance match. A-c voltage was applied by means of a variable transformer to obtain a striking display of continuously changing patterns on the oscilloscope screen. Variable d-c voltage was superimposed (across a potentiometer) to position the pattern on the screen (see cover). Because of the high resolution and intensity of the display, energy shifts back and forth between modes and frequency changes were readily apparent.

Research Under Way

The illustrations at the top of the page are indicative of the good reproducibility obtained with the NBS spectrometer. It provides a rapid means for investigating laser frequencies and modes, since it is possible for the photomultiplier tube to scan a laser frequency spectrum for the oscilloscope in one-sixtieth of a second. Work is therefore under way to expand the instrument's capabilities in order that the fine structures of the frequencies of both visible and infrared lasers may be analyzed. Such analyses should provide information for obtaining laser stabilization. Larger mirror separations than those used in the present experiments will be employed to obtain even higher resolution.

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[1] *For further technical details, see* A new Fabry-Perot spectrometer for high-resolution spectroscopy and laser work, *by K. D. Mielenz, R. B. Stephens, K. F. Nefflen, J. Res. NBS* **68C** (*Eng. and Instr.*) *No. 1, 1 (Jan.–Mar. 1964).*

[2] NBS laser produced interference fringes over 200-meter optical path, *NBS Tech. News Bull.* **47,** *80 (May 1963); also,* Interference fringes with long path difference using He-Ne laser, *by T. Morokuma, K. F. Nefflen, T. R. Lawrence, and T. M. Klucher, J. Opt. Soc. Am.* **53,** 394 (1963).

Carbon Suboxide Structure Proven Linear

THE LINEARITY of the structure of the carbon suboxide (C_3O_2) molecule—a matter of scientific controversy for over 30 years—has been proven with evidence obtained at the Bureau. High-resolution infrared spectroscopic studies by W. J. Lafferty, A. G. Maki, and E. K. Plyler [1] show conclusively that the molecule is a straight chain of three carbon atoms with an oxygen atom at each end.

The electronic structure expected for C_3O_2, as well as valence theory in general, indicates that C_3O_2 has a linear symmetrical structure. In 1933, however, investigators [2] reported a dipole moment that indicated a bent structure for this compound. Since that time, molecular spectroscopists have been divided in their support of linear and nonlinear configurations.

The early work in which a dipole moment was recorded for the molecule has been considered unreliable by some workers because of possible contamination of the sample. Electron diffraction studies [3] indicate that the molecule is very nearly linear, but do not exclude a slightly bent configuration. An attempt to resolve the rotational Raman spectrum [4] was unsuccessful, even though the instrument used could easily resolve the spacing of 0.59 cm^{-1} expected for C_3O_2 if linear. This negative result could indicate a nonlinear structure or could arise from overlapping "hot bands" (bands obtained at room temperature) which obscure the rotational structure of the ground state.

Work [5] performed in 1953 with a small gas sample on a primitive spectrometer in the far infrared region indicated an absorption band in C_3O_2 at about 200 cm^{-1}. Because theory indicates that, if linear, C_3O_2 has seven vibrational frequencies (four stretching and three bending) and only six of these have been experimentally assigned, a number of workers assigned the lowest fundamental bending frequency to this band. However, recent results [6] of a very thorough search of the far infrared region down to 70 cm^{-1} at 0.5 atm pressure and 7.5 m pathlength showed no absorption which could be assigned to the lowest bending frequency.

NBS high-resolution infrared spectrometer used in studies of carbon suboxide. Arthur G. Maki adjusts the mirror which, with the standard lamp, is used to calibrate the instrument. At right is one of the tracings which led the investigators to conclude that carbon suboxide is a linear molecule.

At the Bureau, investigators studied the infrared spectrum of carbon suboxide from 1800 to 3300 cm^{-1}. The NBS-built high-resolution spectrometer which was used was operated in the double pass mode after being calibrated using rare gas emission spectra with an interference fringe system.[7] The resolution obtained was from 0.10 to 0.03 cm^{-1}, and was 0.03 cm^{-1} in the 3180 cm^{-1} region. A liquid-nitrogen-cooled lead sulfide detector and a grating having 10,000 lines/in. were used.

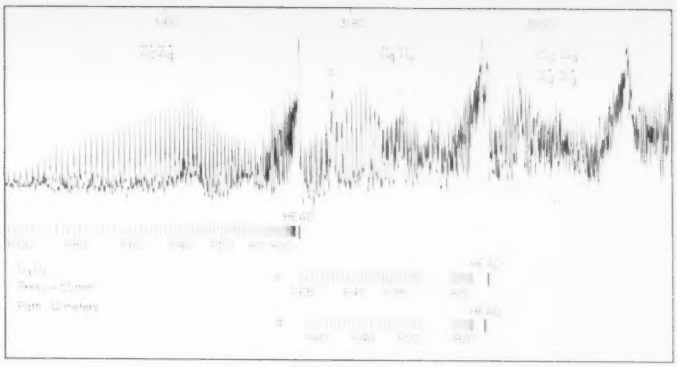
The C_3O_2 samples were donated by Edward Prosen of the Bureau's Physical Chemistry Division. The only impurities found in the samples were minute traces of carbon dioxide, which did not interfere with the study.

The C_3O_2 band centered at 3200 cm^{-1} fortunately falls in the region of peak resolution for the NBS instrument. This spectral region contains a series of resolved absorption bands. This absorption is assigned to a ground state transition which is accompanied by a large number of "hot bands." An analysis of the rotational structure of the ground state transition and of the first "hot band" showed that the selection rules established for a linear molecule are followed.

The many "hot bands" which arise from upper-stage transitions indicate that at least one vibrational fundamental must be of very low frequency. Spectra were taken at -70 to $+180$ °C to find out whether the frequency at the unassigned bending mode could be estimated from the intensity variations. These variations are very minor and provide information for the rough estimate of a bending frequency between 25 and 200 cm^{-1}.

Most of the stronger absorption bands of C_3O_2 show only a maze of lines with no obvious band center. In several weaker absorption bands, however, the "hot bands" are sufficiently displaced from the ground state transition that overlapping is considerably reduced. One of these bands at 3180 cm^{-1} was perfectly suited for analysis with the NBS high-resolution spectrometer.

The first band in the series was found to originate from the ground state. The lines of this band can be accounted for exactly if the band is assumed to arise



Spectrogram of carbon suboxide obtained with a high-resolution infrared spectrometer designed and built at the Bureau. Tracings such as this show conclusively that carbon suboxide is a linear molecule.

from a $\Sigma_u - \Sigma_g$ transition of a linear molecule and to come to a head in the *R*-branch (see spectrogram). The moment of inertia calculated from the data is in excellent agreement with that calculated from electron diffraction parameters. Thus the possibility that this band is due to an impurity is excluded.

An analysis was also possible for the second band in the series. It is a $\pi_g - \pi_u$ transition originating from the first level of a low frequency bending mode. From the *l*-type doubling observed in this band, a second estimate of 20 to 70 cm^{-1} as the frequency of the bending mode can be obtained. This evidence leads to the conclusions that the molecule is linear and that one of the bending vibrations falls at an unusually low frequency.

[1] High resolution infrared determination of the structure of carbon suboxide, *by Walter J. Lafferty, Arthur G. Maki, and Earle K. Plyler, J. Chem. Phys.* **40**, *No. 1, 224–229 (1964).*

[2] *C. G. LeFèvre and J. W. LeFèvre, J. Chem. Soc., 1696 (London, 1935).*

[3] *R. L. Livingston and C. N. Ramachandra Rao, J. Am. Chem. Soc.* **81** *285 (1959).*

[4] *B. P. Stoicheff,* High Resolution Raman Spectroscopy, *Advances in Spectroscopy, Vol.* **I**, *124 (Interscience Publ., N.Y., 1959).*

[5] *H. D. Rix, J. Chem. Phys.* **22**, *429 (1954).*

[6] *F. A. Miller, Preprints of International Symposium on Molecular Structure and Spectroscopy, Tokyo (Sept. 1962). Paper A311.*

[7] *E. K. Plyler and L. R. Blaine, J. Res. NBS* **55**, *279 (1955).*

new publication:

Methods for the Dynamic Calibration of Pressure Transducers

THIS MONOGRAPH is designed to assist the practicing engineer faced with the problem of making dynamic measurements and calibrations of the rapidly changing pressures in missile and space vehicle technology. As pressure changes in rocket engines may exceed 200 psi at frequencies above 10 kc/s, the measurement and calibration requirements of the dynamic pressure transducer are extremely rigorous.

In order to calibrate and use dynamic pressure transducers, the practicing engineer needs to be familiar with (1) the characteristic differential equations and their solutions, (2) the methods of analyzing pairs of input and output functions to determine the transfer function and the frequency response curve, (3) the methods of generating precise input functions, and (4) the specific methods for using precise experimental measurements to determine the dynamic characteristics of a particular pressure transducer. Monograph 67 provides exactly this information, and also provides it, for the first time, in a single reference source.

Publication of this Monograph is part of a continuing program on telemetering transducers which has been conducted in the Mechanical Instruments Section of the National Bureau of Standards under the sponsorship of the Bureau of Naval Weapons; Aeronautical Systems Division, U.S. Air Force; White Sands Missile Range, U.S. Army; and the National Aeronautics and Space Administration. The publication was prepared by Dresser Electronics, Southwestern Industrial Electronics Division, under contact with the National Bureau of Standards.

Methods for the Dynamic Calibration of Pressure Transducers, by J. L. Schweppe, L. C. Eichberger, D. F. Muster, E. L. Michaels, and G. F. Paskusz; National Bureau of Standards Monograph 67; December 12, 1963; 104 pages; 60 cents. (Order from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402.)

NBS Antarctic Pro

ANTARCTIC RESEARCH projects are a part of the participation of the NBS Boulder (Colo.) Laboratories in the International Year of the Quiet Sun (IQSY). These projects constitute an exciting study of electromagnetic phenomena, characteristics and behavior of the ionosphere, and effects of solar activities on radio transmissions. NBS involvement in Antarctic research began during the International Geophysical Year (IGY, 1957–1958).

Data to be collected during the coming year are of particular interest because of the expected reduction in solar activity. The exchange of data gathered by scientific communities of nations participating in the program of IQSY will lead to an increased interest in the Bureau's Antarctic program. Bureau research will be intensified, and since all Bureau programs involve measurements that are affected by conditions on the sun, this period should yield data showing significant changes in the earth's physical environment.

Stephen S. Barnes is coordinator of the programs for the Boulder Laboratories, and Robert T. Frost is coordinator between the Bureau and the National Science Foundation, which provides most of the funds for equipment and installations. The scientific personnel are employees of the Bureau and work closely with scientists from universities and nongovernmental agencies and with scientific leaders from other nations. The U.S. Navy supplies logistic and housekeeping services for the bases.

The Boulder Laboratories will conduct four major research programs in the Antarctic. Three of these—vertical incidence ionospheric soundings, radio noise, and measurements at conjugate points—are continuing studies. One new program, on forward scatter, will be started during the coming year.

Conjugate-Point Program

The conjugate-point program of the Boulder Laboratories includes four distinct studies: riometer measurements of absorption in the ionosphere; photometer measurements of aurora and airglow; recording of VLF emissions; and the observation of magnetic micropulsations. H.J.A. Chivers coordinates the program for the Boulder Laboratories.

Six stations, three in each polar region, are involved in the conjugate-point program. They are connected in pairs by magnetic field lines of the earth. Three of the stations, South Pole, Byrd, and Eights, are Antarctic bases of the United States Antarctic Research Program. Their Canadian conjugates are Frobisher Bay, Great Whale River, and Baie St. Paul, respectively.

Riometer Measurements of Absorption. Under the direction of J.K. Hargreaves, riometers (*r*elative *i*onospheric *o*pacity *meters*) will be operated at all three of the Antarctic stations. These devices measure the absorption of cosmic radio noise in the ionosphere. Because absorption is strongly dependent on solar activity, the forthcoming period of minimum solar activity (IQSY) affords an opportunity to study this high-latitude phenomenon under relatively simple solar conditions.

***USNS Eltanin* before departing [illegible] duty s**

Since the presence of absorbing patches in the ionosphere affects radio propagation, a study of the extent, movement, and intensity of these patches might have value in propagation predictions. Such a study might lead to discovery of the basic mechanisms of auroral phenomena which, in turn, are related to the environment of the energetic particles (mainly of solar origin) around the earth.

Photometer Measurement of Aurora and Airglow. A photometer at Eights station is used to collect visual

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parting for duty station in Antarctic waters.

data on the emissions of ionized nitrogen, atomic oxygen at 100 km, and atomic oxygen at 300 km. This project is directed by Michael Gadsden. Comparisons are made with similar data collected at Baie St. Paul, Canada, to see whether a correlation exists between the conjugate points in this area of study. A similar study of airglow and auroral emissions was begun at Hallett in Antarctica in 1960 under the direction of Franklin Roach. The study is designed to increase knowledge of local space and of the physics of the upper atmosphere. It is hoped that measurements at Antarctic sites will continue until the next sunspot maximum.

Recording VLF Emissions. Under the leadership of Roger M. Gallet, collection of data for the VLF emission study has been in progress at Eights station since late in 1961. During 1963 the VLF observations were made at both the Eights and Byrd stations, but in 1964 the NBS portion of the study will be continued only at Eights.

The purpose of the VLF emissions program is to extend scientific knowledge and understanding of the magnetosphere, the region in which the earth's magnetic force is dominant. The VLF signals are believed to result from an emission process in which very-low-frequency waves are excited by bunches and streams of high-speed ionized particles moving in the magnetosphere. The VLF waves are guided along the magnetic lines of force and thus can be observed at magnetically conjugate points. These signals therefore reflect some of the dynamic properties of the magnetosphere.

The VLF emissions are recorded in two ways. A continuous record of the emissions is made on a hiss recorder. Because of the slow recording rate, only profiles of the emissions are discernible. The individual emissions are studied on a magnetic tape recorder operated for 2 min of each hour. This recorder has a high resolution in time that makes possible identification of the individual emissions. VLF emission events which occur while both recorders are in operation allow a study of the fine structure of each event as well as of the overall pattern.

Preliminary results obtained at Antarctic and other sites indicate a possible correlation between the VLF emission data and data obtained in other phases of the conjugate-point program, such as the *D*-region absorption events observed with riometers.

Observing Magnetic Micropulsations. Another phase of the conjugate-point program is the study of micropulsations (natural electromagnetic field fluctuations in the frequency range of 3.0 to 0.001 c/s). This study, directed by Wallace H. Campbell, is one of many being conducted within an extensive worldwide network of stations. Equipment for micropulsation data collection was installed at Byrd and Eights stations during the past year. The data collected are transmitted to the Boulder Laboratories for recovery and interpretation. The equipment operator is shared with the other phases of the conjugate-point program.

Design of equipment for this program is crucial because of the difficulty presented by the extremely low frequencies. A 6-ft loop antenna wrapped with 16,000 turns of wire (approximately 60 mi) is used to receive the signals. The signals are fed from the antenna through a solid-state chopper amplifier and then recorded on a special FM magnetic tape recorder. The recorded signals are too slow to be studied in their original form; therefore, the tape is played back at about 3,000 times the recording speed to raise the signals to the kilocycle range. The signal is also fed through a frequency compensation amplifier and then to a chart recorder to recover the data in graphic form.

Harry Sellery, Chief of the Field Engineering Section, at South Pole Station on an inspection trip.

The micropulsation study is intended to extend basic knowledge of the physics of the radio propagation medium. There is a possible correlation between this study and the VLF emission and the airglow and aurora studies.

Ionospheric Soundings Program

One of the original NBS programs in the Antarctic is the ionospheric soundings program led by William Hough. Preparations for the continuing program began in 1955, and the stations at Byrd and South Pole were in operation by 1957. The chief item of equipment used in the ionospheric soundings is the ionosonde, a radar-type instrument that sends a signal to be reflected from the underside of the ionosphere. The signal is timed so as to measure height and density of the ionospheric layer.

The data obtained from the vertical incidence ionospheric observations will be studied in conjunction with data provided by programs of auroral and geomagnetic observations and also with data from a worldwide network of other stations to predict radio communications propagation conditions. Data that were unavailable before the Antarctic ionosphere stations were established have increased the accuracy of this prediction service as these data are necessary for predicting radio communications paths across the South Polar regions. A future use of these data will be to correlate them with data obtained by the proposed topside sounder satellites. Such a correlation will give a more complete profile of electron density of the upper atmosphere.

A new ionospheric sounder antenna was constructed at South Pole station during the 1963–64 Antarctic summer season. This new antenna was required because of changes in the electron density of the ionosphere resulting from reduced solar activity. The C–3 ionosonde will also be improved by replacing the transmitters and receivers with C–4 components.

Radio Noise Program

The radio noise program, directed by Robert Disney, shares the distinction with the ionospheric soundings program of being one of the original NBS programs in the Antarctic. Measurements of radio noise are being made abroad the *USNS Eltanin*, the only seaborne station in the NBS Antarctic effort. The *Eltanin* covers a course from 60° south to the Antarctic ice pack in a series of cruises of 1 to 2½ months duration. Land-based measurements for this program are being made at Byrd station. These two stations are part of an eighteen-station network covering every continent. The stations measure radio noise from 13 kc/s through 20 Mc/s at eight discrete frequencies 24 hr a day, 7 days a week.

An ARN 2 radio noise recorder is used to gather the data. The equipment is automatic and needs only daily calibration. The operator scales and tabulates the data and sends them out once a month in coded radiograms to Washington, D.C., for forwarding to Boulder, Colo., by teletype. Once a year, all original records are sent to Boulder for additional analysis.

The data are also used in reports to the Consultative Committee on International Radio of radio noise predictions and in designing communications systems.

Forward Scatter Program

The forward scatter project is a new portion of the NBS Antarctic program for the coming year. The main objective of the program will be detection of distinct solar cosmic-ray emission events and investigation of their spectral, geographical, and temporal variations. Subsidiary objectives include study of seasonal and diurnal variation of the scatter signal intensity, sporadic-*E* propagation, phenomena associated with auroral ionization, and meteoric ionization.

Radio propagation by forward scatter is believed to occur from a large number of small irregularities in

the ionization of the lower atmosphere which scatter radio waves in all directions (but predominantly forward), much as light is scattered from the large number of small water droplets in a cloud or fog. One of the major factors contributing to the ionization of the lower ionosphere is corpuscular radiation of ionized atomic particles of solar and galactic origin.

In the past, observations of solar proton emissions by the forward scatter technique have been made almost entirely during periods of moderate to high solar activity and on frequencies between 32 and 36 Mc/s. The Antarctic scatter links have been made particularly sensitive to the very small, but highly interesting, solar cosmic-ray events that are expected to occur during the IQSY—at the minimum phase of the solar cycle—by modifying equipment and lowering operating frequencies to 23 to 24 Mc/s. Transmission will be continuous wave with interruption every half hour to permit observation of the background noise level.

Responsibility for analyzing the data will be shared by D. K. Bailey, project leader for the Bureau, and Dr. M. A. Pomerantz, Director, Bartol Research Foundation, Swarthmore, Pa. Initial impetus for the project was provided by a recommendation from Bailey to the Scientific Committee for Antarctic Research (SCAR), which recommended it to the member nations.

This program will be an international effort since, because of the long radio paths involved, a Soviet station, Vostok, and a British station, Halley Bay, will be used as receiving stations. McMurdo and South Pole stations will be used for both transmitting and receiving, while Byrd will be transmitting only. Ionospheric forward scatter observations among these stations will provide continuous monitoring at fixed locations of the flux of protons and heavy nuclei in a range of energies not accessible to other ground-based techniques. In this area, it will supplement cosmic-ray studies.

Construction of antennas at the three U.S. stations and Vostok will be done by U.S. Navy construction units. Design and installation of electronic equipment are entrusted to the Bureau. Two electronic engineers from the Radio Systems Division will go to the Antarctic late in December to supervise and inspect the installation at the U.S. and Soviet stations. Data collection and field analysis will be made by Bartol representatives in the Antarctic.

The three most prominent surface constructions at Byrd Station. Left to right, the balloon launching tower, the weather balloon tracking tower, and the aurora tower.

John D. Jacobs, a graduate student in physics at the University of Alaska, will operate the forward scatter receiver at Vostok for the coming year. This marks the first time that an American scientist has been permitted to conduct research at the Soviet station at Vostok under the terms of the twelve-nation Antarctic treaty for peaceful scientific research.

NBS–BL personnel who will operate the equipment for data collection are: Dean Thomas aboard the *USNS Eltanin;* Steffen Maagol, who replaces Lorne Matheson at Eights; David Webster and Dale Blake, who replace David Lewis and Dale Vance at Byrd; and Howard Sargent and William Wiest, who replace Robert Burgess and James Petlock at South Pole.

Inspection, construction, and equipment modification at the Antarctic stations were undertaken by William Hough, Dr. Wallace Campbell, Wesley Harding, Milton Woodward, and Robert Disney.

The need continues for engineers and physicists to man the National Bureau of Standards stations in the Antarctic. Interested applicants should contact:

Personnel Office
National Bureau of Standards
Boulder Laboratories
Boulder, Colo. 80310.

Purity Determination by Dielectric Cryometry

NBS CHEMISTS have devised an accurate method, known as dielectric cryometry, for determining the purity of small samples of nonconducting compounds.[1] In developing this method, G. S. Ross and L. J. Frolen designed a capacitance cell that permits the dielectric constant of samples to be measured continuously as the substance is melted or frozen. A relatively large change in dielectric constant accompanies this phase change. The measured dielectric constant change, expressed as a function of the fraction melted, is correlated with the accompanying change in temperature to determine the purity of the sample. Because dielectric cryometry is nondestructive and its accuracy is nearly independent of the sample size, it should be extremely useful as a means of determining sample purity.

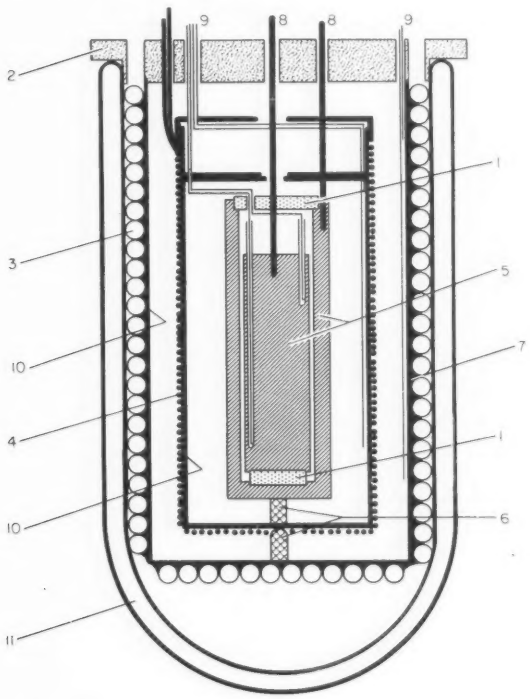
The properties of chemical compounds are used extensively in standardization measurements of many kinds. Both the precision and accuracy of these measurements depend on the purity of the material used as a standard. In the usual cryometric procedures to determine purity, the change in heat content or change in volume of the substance is measured and correlated with the accompanying change in temperature while the sample is melted or frozen. To obtain high accuracy, relatively large samples must be used.

NBS chemists engaged in providing standard reference materials and procedures for science and industry

therefore sought a method of purity analysis whose accuracy would be independent of sample size.

In this method, the dielectric constant of a material is measured while the substance is melted or frozen. The difference in dielectric constant between a solid and a liquid of the same material is relatively great although the corresponding temperature change is quite small. If the dielectric constant change between the solid and liquid state of a material is linear with respect to the fraction of the sample melted, then a plot of temperature versus dielectric constant approximates a hyperbola. Either a projection method or a least-squares fitting of the data permits calculation of both the freezing point of the pure material and the freezing point of the actual sample. These two values are used to evaluate the purity of the material.

The capacitance cell employed in these determinations consists of an outer brass can and a solid brass cylinder that fits inside. Each of these cylinders acts as a plate of a capacitor, with the test material filling the 1.5-mm space between the plates. Concentric to the outer brass can are heating and cooling coils for controlling the temperature of the material under examination. The entire device is contained in a 4-liter Dewar to isolate it from environmental effects. All electrical leads pass through an insulated cover to an auxiliary apparatus employed to measure, record, and control the temperature, and to measure and record the capacitance of the cell.



Cross-sectional drawing of capacitance cell employed in NBS purity determinations by dielectric cryometry: (1) quartz separators, (2) cell cover, (3) cooling coils, (4) heating wire, (5) cell walls, (6) spacers, (7) insulation, (8) electrode leads, (9) thermocouple leads, (10) brass containers, and (11) Dewar.

The substance to be examined is poured into the void between the plates of the capacitor cell. The cell is first cooled to freeze the substance quickly, thereby retaining a homogeneous dispersion of the impurities in the material. Then the cell is warmed to a temperature near the melting point of the material, and is slowly warmed further while the capacitance is measured continuously. This measurement continues for 6 to 12 hr until all the material is melted.

In some experiments the sample was alternately frozen and melted as the capacitance was measured. So far as could be observed the resulting curves were exactly superimposed which illustrates one of the important advantages of the dielectric method over the thermometric method, namely that constancy in the melting rate is not necessary and that the melting sequence can even be interrupted by a period of refreezing without appreciably influencing the determination.

The materials which may be analyzed in this apparatus by dielectric cryometry are limited to those that are nonconducting, those that are at least 99 percent pure, and those that will change state within the temperature limits of the equipment (-100 to $+250$ °C). Many organic compounds fall into this group. The Bureau studies were conducted on five different organic compounds having diverse dipole moments and polarizabilities: benzene, nitrobenzene, *p*-dichlorobenzene, naphthalene, and 2-methylnaphthalene. The calculated impurity content of the samples analyzed ranged from 100 to 2,000 ppm, and the estimates of standard deviation were consistently less than 2 percent of the average impurity. Within the same range of purity, estimated standard deviations greater than 4 percent are usual when the analysis is performed using precision thermometric (time-temperature) cryometry.

The principles of dielectric cryometry may also be applied to the operation of precise temperature-controlling mechanisms. The large, easily detectable change in dielectric constant of a substance as it changes state is accompanied by only a small temperature change. A capacitance cell can be employed to detect this small change and to actuate heating or cooling devices as required.

Preliminary investigations at the Bureau show that temperature can be manually controlled to within ± 0.0001 °C when the capacitance cell is employed as a dielectric temperature detecting device. Direct extrapolation of the data obtained in these investigations indicates that temperatures may be controlled to within one microdegree with a redesigned capacitance cell and an automated temperature controlling device. Although in practical application such precision is probably not feasible at this time, control of temperature variation to less than 0.0001 °C seems quite possible.

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[1] *For further information see* Chemical purity by dielectric cryometry, *J. Res. NBS* **67A**, (*Phys. and Chem.*), *607–614 (Nov.–Dec. 1963)*.

Investigation of "Chorus"

Natural VLF Emission

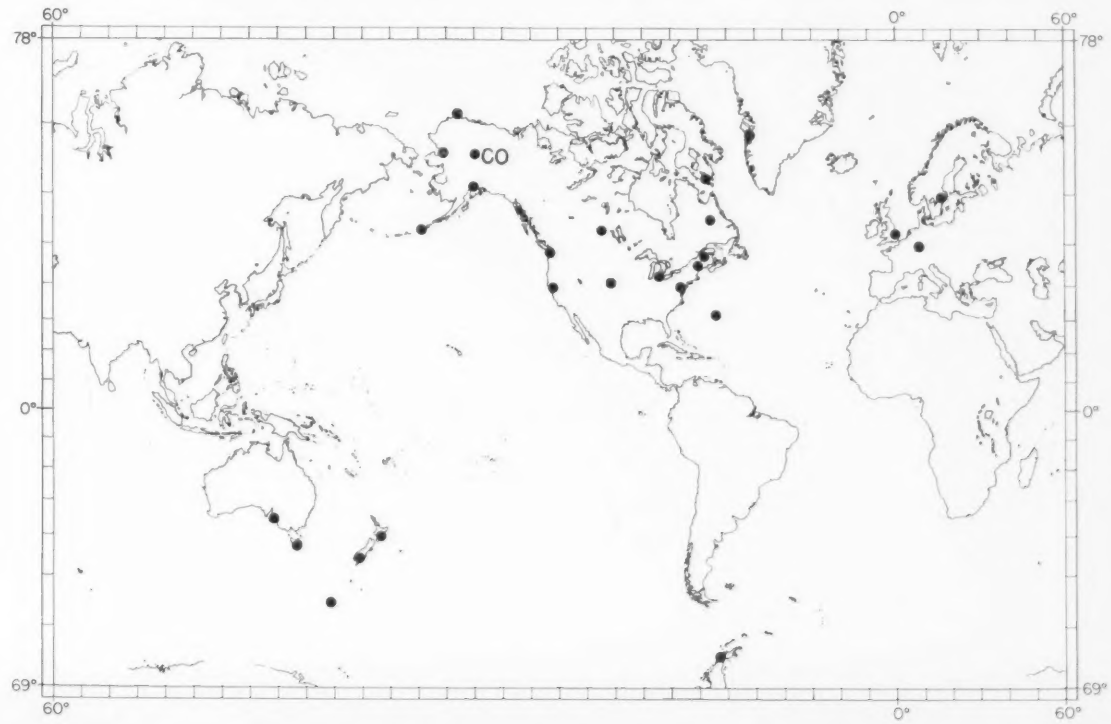
CHORUS, a natural electromagnetic phenomenon in the very low frequency (VLF) range, probably originates in the exosphere. An understanding of this phenomenon can lead to an enhancement of knowledge of the environment of the exosphere and ionosphere. The Bureau is investigating chorus in an attempt to determine its origin. In this study, sponsored by the Air Force Cambridge Research Laboratories, physicist Joseph H. Pope of the NBS Boulder Laboratories has used data obtained from 29 widely distributed VLF-monitoring stations, many of them set up to record data on "whistlers" during the International Geophysical Year (IGY).[1] His treatment of this wealth of data showed chorus to occur most often at geomagnetic latitudes between 60° and 70° in both the Northern and Southern hemispheres. Analysis of the times and locations of chorus at the participating stations shows that it appears in regular diurnal and seasonal patterns which vary with time and place. These patterns are now being studied to determine the overall pattern of chorus manifestation.

Characteristics and Origin of Chorus

Chorus, originally named dawn chorus for its resemblance to sounds of birds in the English countryside at dawn, generally consists of a multitude of rising tones. Each tone rises from 1 to 2 kc/s to 3 to 4 kc/s, usually lasting 0.1 to 0.5 sec. Chorus is often accompanied by noise or hiss, covering the same frequencies as those contained in the chorus. Often it will occur in bursts, starting from a background of little or no chorus, rapidly building up in intensity and repetition rate, and then receding to background noise.

No adequate theory of the origin of chorus is accepted, although several hypotheses have been proposed. The best known is the traveling-wave hypothesis; [2] others include plasma oscillations in the exosphere,[3] Cerenkov radiation,[4] and radiation from protons spiraling down the field line with gyromagnetic frequency Doppler-shifted by an amount depending on the velocity of the particles and the ambient

Data used in NBS study of "chorus" originated from the worldwide array of whistler-study stations shown on this map. Many of the data were obtained during participation of these stations in the IGY program. Continuous data from the beginning of 1956 to the present were provided by the College, Alaska, station (CO), one of the three operated by the Geophysical Institute of the University of Alaska.



electron density.[5] This last hypothesis is supported by results obtained by Murcray and Pope.[6]

Observing Chorus

Since chorus is an ELF/VLF emission it can be received on equipment for listening to "whistlers," another VLF phenomenon. This has made many stations readily available for chorus observations. The equipment used consists of a VLF antenna, an amplifier having a voltage gain of about 10^6 and a bandpass from 500 c/s to 15 kc/s, and a tape recorder. The antenna used at the College, Alaska, station, for example, is a delta-shaped loop antenna 30 ft high and 60 ft across the base.

Chorus activity is sampled at each participating station by recording it on magnetic tape for 2 min of each hour, beginning at 35 min past the hour. The strength of each chorus sample is evaluated as an integer on a 0 to 5 scale by monitoring technicians, each of whom is specially selected on the basis of his audio responses.

Observations recorded at 29 whistler stations were used in the NBS study of chorus. Three of the stations (the College, Kotzebue, and Barrow stations) were operated by the Geophysical Institute of the University of Alaska. The rest were scattered over the western hemisphere and Europe, from Alaska to Antarctica, and from Sweden westward to Australia. Observations were made of chorus at the College, Alaska, station from 1956 to the present, and at each of the other stations for several years, including the IGY.

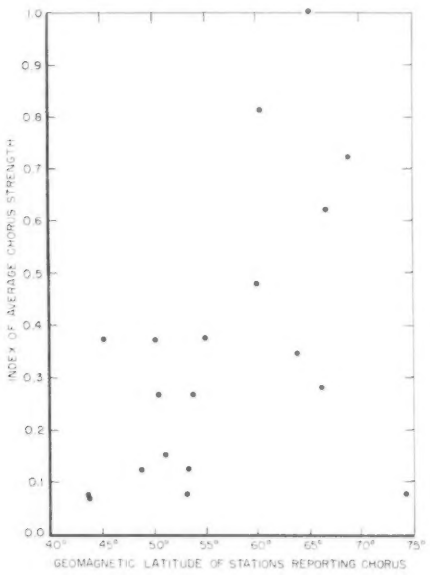
Variations in Chorus

The occurrence of chorus is greatest in the regions between 60° and 70° geomagnetic latitude in both hemispheres. While experimental scatter prevents more accurate determination of this region, the correspondence with the auroral zones seems significant.

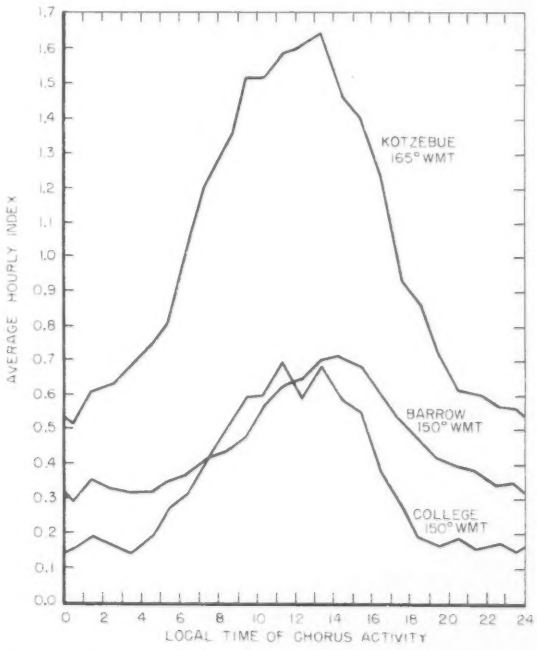
Chorus activity shows seasonal variations at all stations, but not in the same pattern for all; some stations exhibit maxima during winter and others during summer. However, chorus activity does seem to reach its peak during summer at stations at low latitudes and in winter at high latitudes, although additional evidence is needed to render this finding conclusive.

All stations examined show a definite diurnal variation and, as has been known for some time, a time of diurnal maximum related to the latitude of the station. Above the zone of auroral maximum, however, this dependence breaks down. A pronounced delay in diurnal peak with increasing geomagnetic latitude is evident, particularly in the plot of diurnal peak against "eccentric geomagnetic latitude." [7]

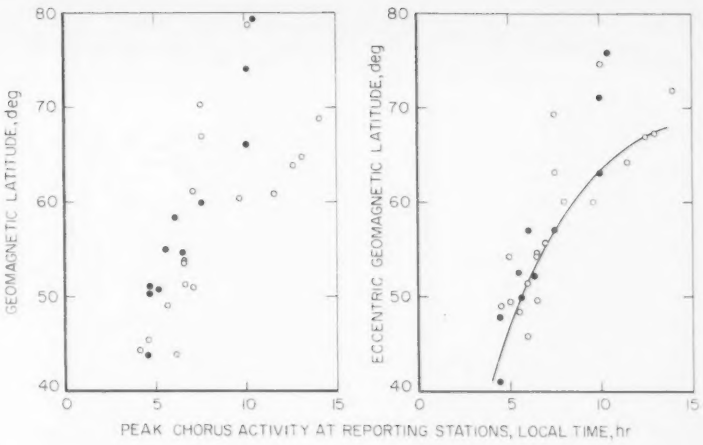
Chorus is found to be somewhat related to geomagnetism, having a positive correlation index of 0.5 to 0.6 with the geomagnetic *K*-indices (an approximate measure of solar-terrestrial particle activity as determined from magnetograms) in the lower latitudes. At the high latitudes, however, the correlation varies with the season in a complex way, being positive near the solstices and negative near equinoxes.[8]



The average index of chorus was greatest at stations between latitudes 60° and 70°, North and South. Stations reporting indexes above 0.5 are those located at College, Alaska; Macquarie Island (near Antarctica); Barrow, Alaska; and Ellsworth, Antarctica.



"Chorus" has long been known to have similar daily peaks at different locations. The hourly average index of chorus activity is similar in shape for three different Alaskan stations, although greatly different in level.



Time of the daily peak of chorus activity varied with the latitudinal location of the station, from before 0500 at Bermuda to after 1300 at three Alaskan stations (Barrow, College, and Kotzebue). The South Pole and Godhaven, Greenland, stations had peaks near 1100.

Frequency of Chorus

Chorus varies greatly in its frequency—the tone may either ascend or descend, or even consist of simultaneously ascending and descending branches. It may warble or be relatively steady. Statistical studies of chorus frequencies can be made using the highest frequency, the lowest frequency, the mid-frequency, and the rate of change of frequency. An earlier study at the College, Alaska, station [8] showed that the mid-frequency varies diurnally. The maximum frequency was used in the studies reported here, to avoid the greater influence of harmonics of powerline noise on measurements of minimum frequency and mid-frequency.

Plots of variation of maximum frequency against season and hour of day at the Barrow, College, and Kotzebue Alaskan stations show a marked similarity. Not only are maximum frequency patterns similar for the three stations for the measured years, but the plots of average maximum frequency during a day were similar for the three Alaskan stations, each approaching a marked diurnal peak in the evening hours before midnight. Further analysis of the rates of chorus frequency changes observed at the three stations showed a surprising similarity, both among stations and for different years.

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[7] The eccentric geomagnetic dipole, *by W. D. Parkinson and J. Cleary, Geophys. J.* **1,** *346 (Dec. 1958).*

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Periodicals

Technical News Bulletin, Volume **48**, No. 2, February 1964. 15 cents. Annual subscription: $1.50; 75 cents additional for foreign mailing. Available on a 1-, 2-, or 3-year subscription basis.

CRPL Ionospheric Predictions for May 1964. Three months in advance. Number 14, issued February 1964. 15 cents. Annual subscription: $1.50; 50 cents additional for foreign mailing. Available on a 1-, 2-, or 3-year subscription basis.

Journal of Research of the National Bureau of Standards

Section A. Physics and Chemistry. Issued six times a year. Annual subscription: domestic, $4; foreign, $4.75.

Section B. Mathematics and Mathematical Physics. Issued quarterly. Annual subscription: domestic, $2.25; foreign, $2.75.

Section C. Engineering and Instrumentation. Issued quarterly. Annual subscription: domestic, $2.25; foreign, $2.75.

Section D. Radio Science. Issued monthly. Annual subscription: domestic, $9; foreign, $11.50.

Current Issues of the Journal of Research

J. Res. NBS 68B (Math. and Math. Phys.), No. 1 (Jan.–Mar. 1964).

A note on a generalized elliptic integral, G. H. Weiss.

An asymptotic expansion for the multivariate normal distribution and Mill's ratio, H. Ruben.

Calculation of certain multiple generating functions, G. H. Weiss.

Some infinite sums involving zeros of $J_0(x)$, L. F. Epstein.

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A Fabry-Perot spectrometer for high-resolution spectroscopy and laser work, K. D. Mielenz, R. B. Stephens, and K. F. Nefflen.

Variable impedance power meter, and adjustable reflection coefficient standard, G. F. Engen.

A laser with a multihole diaphragm, T. Morokuma.

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Reference tables for thermocouples of iridium-rhodium alloys versus iridium, G. F. Blackburn and F. R. Caldwell.

Radio Sci. J. Res. NBS/USNC–URSI, Vol. 68, No. 3, Mar. 1964.

An interpretation of rapid changes in the phase of horizontally polarized VLF waves recorded at night over a short path in the southwestern United States, E. E. Gossard and M. R. Paulson.

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On the long-term phase stability of the 19.8 kc/s signal transmitted from Hawaii, and received at Boulder, Colorado, A. H. Brady.

Oblique propagation of groundwaves across a coastline. Part III, J. R. Wait.

Impedance of a monopole antenna with a radial-wire ground system on an imperfectly conducting half space, Part III, S. W. Maley and R. J. King.

A simplified theory of diffraction at an interface separating two dielectrics, J. Kane and S. N. Karp.

Variational solution for the admittance of long cylindrical antenna, R. A. Hurd.

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Propagation of plasma waves in a "spoke-wheel" magnetic field, R. L. Liboff.

An experimental investigation of signal strength in the area around a transmitter's antipode, R. M. Pipp and J. B. Webster.

Relationship between simultaneous geomagnetic and ionospheric oscillations, H. Rishbeth and O. K. Garriott.

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Curves of input impedance change due to ground for dipole antennas, L. E. Vogler and J. L. Noble, NBS Mono. 72 (Jan. 31, 1964), 35 cents.

Safety standard for non-medical x-ray and sealed gamma-ray sources, Part I. General, NBS Handb. 93 (Jan. 3, 1964), 30 cents.

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Vitreous china plumbing fixtures, CS20–63, 20 cents (supersedes CS20–56).

Forms for two-way concrete joist floor and roof construction, SPR265–63, 5 cents.

Gypsum board products, SPR266–63, 10 cents.

Publications in Other Journals

This column lists all publications by the NBS staff, as soon after issuance as practical. For completeness, earlier references not previously reported may be included from time to time.

Knight shifts and line widths of the nuclear magnetic resonance of Pb^{207} in lead-indium alloys, R. J. Snodgrass and L. H. Bennett, Phys. Rev. **132,** 1465–1474 (Nov. 15, 1963).

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